

UNITED STATES PATENT APPLICATION

FOR

METHOD AND APPARATUS

FOR

PARALLEL OPTICAL INTERCONNECTION

OF

FIBER OPTIC TRANSMITTERS, RECEIVERS AND TRANSCEIVERS

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METHOD AND APPARATUS
FOR
PARALLEL OPTICAL INTERCONNECTION
OF

5 FIBER OPTIC TRANSMITTERS, RECEIVERS AND TRANSCEIVERS

CROSS REFERENCE TO RELATED APPLICATION

This application claims the benefit and is a continuation-
in-part of U.S. Patent Application Serial No. 09/321,308,
10 filed on May 27, 1999 by Wenbin Jiang et al. having Attorney
Docket No. 003918.P003 which is hereby incorporated by
reference and also claims the benefit of and is a
continuation-in-part of U.S. Patent Application No.
09/320,409, filed on May 26, 1999 by Wenbin Jiang et al.
15 having Attorney Docket No. 003918.P002 which is hereby
incorporated by reference, both of which are to be assigned to
E2O Communications, Inc.

FIELD OF THE INVENTION

This invention relates generally to light coupling devices.
20 More particularly, the invention relates to fiber optic
modules.

BACKGROUND OF THE INVENTION

Fiber optic modules interface optical fibers to electronic
circuitry transducing communication by light or photons with
25 communication by electrical signals. A fiber optic module may

be a fiber optic receiver, transmitter or transceiver including both receive and transmit functions. The fiber optic receiver, transmitter and transceiver each have optical elements (OE) and electrical elements (EE). The fiber optic transmitter OE includes an emitter (such as a semiconductor LED or Laser) mounted in a package and an optical coupling element for coupling light or photons from the OE into the optical fiber. The type of semiconductor laser (light amplification by stimulated emission of radiation) may be a vertical cavity surface emitting laser (VCSEL). The fiber optic receiver OE includes a photodetector (such as a photodiode) mounted in a package and an optical coupling element for coupling light or photons from the optical fiber into the photodetector. The EE for each includes integrated circuits, other active elements and passive elements mounted on a substrate such as a printed circuit board (PCB) or ceramic. The OE and EE are connected electrically at the emitter and photodetector.

Because of the high modulation frequencies utilized in fiber optic communication, crosstalk between receive and transmit signals and electromagnetic interference (EMI) is of concern. In order to reduce EMI, shielding of the high frequency electrical components is required which is usually accomplished by attaching a metal shield to the substrate of the fiber optic module and connecting it to ground. Rapidly

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increasing internet traffic has created a demand for low cost
fiber optic devices with bandwidth capabilities up to 40
Gigabytes per second (Gbps) for distances up to 300 meters
without sacrificing the quality of the fiber optic link. In
5 order to meet the bandwidth demands, it is desirable to
provide parallel fiber optic data links with four, ten or
twelve channel VCSEL arrays each operating at 1.25 gigabytes
per second (Gbps), 2.5 Gbps or up to 10 Gbps. Each VCSEL in
the VCSEL array is, spaced apart at 250 μ m and coupled in
10 parallel to a fiber optic ribbon cable. Such small spacing
between each VCSEL in a VCSEL array allows for compact
packaging of a VCSEL array which can be used in a multiple
channel laser transmitter or transceiver. However, the
tightly packed VCSELs in the VCSEL array having such small
15 spacing there between introduces some challenges. One
challenge which is difficult to overcome is separately
monitoring the output power of each VCSEL in the VCSEL array
when they are so tightly spaced and packaged together.

To maintain the quality of multiple channels providing
20 multiple fiber optic data links, monitoring the output power
of each individual VCSEL is important in order to assure
signal quality. It is desirable to maintain a constant output
power over temperature variations and time. To maintain a
constant output power, each individual VCSELs operation needs
25 to be separately monitored and optimized over time due to

temperature variations, aging, and other effects.

Additionally, the close spacing of the VCSELs in a VCSEL array aggravates the difficulty of placing EE components and

interconnections on a printed circuit board. Additionally,

5 the close spacing of VCSELs in the VCSEL array complicates any optical alignment needed between EE and OE components and the fiber optic cable. A VCSEL array necessitates five dimensional alignment between the EE and the OE in the X, Y, Z axes and along the axes of rotation and of tilt for each VCSEL in the
10 VCSEL array. To provide five dimensional alignment, expensive packaging and packaging tools are required.

Another disadvantage to VCSEL arrays is that power output is highly localized due to the tightly spaced VCSELs in the VCSEL arrays. Combining the output power of all the VCSELs in
15 the VCSEL array, the combined output power exceeds IEC Class - 1 eye safety limit. This necessitates the special handling of the data link modules when powering the VCSEL array such as when plugging it into a printed circuit board. Otherwise, harm may result to a user's eyes if the user accidentally
20 looks into the laser beams from the VCSEL array.

For commercial acceptance, fiber optic modules generally must comply with existing industry standards such as the Hot pluggable Gigabit Interface Converter (GBIC) de facto industry standard. The details of the GBIC standard are set forth in
25 SFF Committee Proposed Specification for GBIC (Gigabit

Interface Converter), Rev. 5.4, August 16, 1999, the disclosure of which is incorporated herein by reference. Because of the relatively large size of GBICs, end users desire more compact, high throughput fiber optic transceivers.

5 Particularly, end users desire a GBIC in a small form pluggable (SFP), LC package.

10 It is desirable to improve upon the prior art. There is a need to support high bandwidth links whose output power can be monitored and optimized over temperature variations and time, while overcoming EMI and eye safety concerns. There is a need to provide simplified alignment in a multichannel fiber optic module to reduce costs. Moreover, there is a need for fiber optic modules meeting these needs, yet still conforming to industry standards.

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BRIEF SUMMARY OF THE INVENTION

Briefly, the present invention includes a method, apparatus and system as described in the claims.

Parallel fiber optic transmitter and receiver channels are
5 implemented within a fiber optic module having LC connectors
or other small form factor connectors. The fiber optic module
is implemented with an optical element and an electrical
element. The fiber optic module includes a printed circuit
board (PCB) having one or more edges that serve as guide rails
10 that can electrically and mechanically couple to one or more
guide rail slots of a module cage. The module cage formed of a
conductive material has the one or more guide rail slot which
in themselves are conductive to electrically and mechanically
couple to the one or more guide rails of the fiber optic
15 module. The metallized module housing provides an internal
electromagnetic interference shield which is coupled to the
guide rail slot of a module cage and a ground plane of a host
or daughter card printed circuit board (PCB) as well as to a
chassis ground. The grounding to the chassis is achieved by
20 the module cage tabs which protrude from the cage housing and
can electrically couple the internal electromagnetic
interference shield and the one or more guide rail slots to
the chassis ground. The cage is therefore in contact directly
with the system chassis both mechanically and electrically for

grounding. The arrangement allows fiber optic module to "hot plug" or be physically inserted and withdrawn during system operation without causing damage to either the fiber optic module or the system.

5 Alternatively, when a hot plug-in application is not required, the fiber optic module can be in fixed electrical interface format where the fiber optic module is directly soldered onto the daughter card or the system circuit board without the use of any cage. The fiber optical module
10 grounding is provided by electrical contact directly with the grounding plane of the daughter card or the system circuit card through electrical interfaces of the fiber optical module.

15 The fiber optic module supports multiple combinations of fiber optic channels for transmitting, receiving or transceiving signals. The fiber optic module housing and the cage for the module may be formed of a conductive material such as a metal or include conductive plating to provide the conductive guide rail slots, and tabs for internal EMI
20 shielding and allowing the module to be hot plugged into the cage. Additionally, fiber optic connectors besides LC connectors may be used such as SC, MT - RJ, or MU connectors to provide an optical interface of the module to the fibers.

BRIEF DESCRIPTIONS OF THE DRAWINGS

Figure 1A is a simplified top cutaway view of a fiber optic module for an embodiment of the present invention.

Figure 1B is a simplified top cutaway view of a fiber optic module for another embodiment of the present invention.

Figure 2 is a simplified top cross - sectional view illustrating an optical element OE for an embodiment of the present invention.

Figure 3 is an exploded view of the optical block of the optical element for a preferred embodiment of the present invention.

Figure 4A is an exploded view of the fiber optic module, module cage, and host PCB of the present invention .

Figure 4B is a magnified cross sectional view from the side of the fiber optic module, module cage and a printed circuit board of the present invention coupled together.

Figure 5A is a top view of a locking mechanism of the present invention in a locked position to couple the fiber optic module, the module cage, and the host PCB together.

Figure 5B is a top view of the locking mechanism of Figure 5A in an unlocked/ejected position.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

In the following detailed description of the present invention, numerous specific details are set forth in order to provide a thorough understanding of the present invention.

5 However, it will be obvious to one skilled in the art that the present invention may be practiced without these specific details. In other instances well known methods, procedures, components, and circuits have not been described in detail so as not to unnecessarily obscure aspects of the present
10 invention.

The present invention includes a method, apparatus and system for parallel optical interconnection of fiber optic transmitters, receivers, and/or transceivers.

Referring now to Figure 1A, a simplified cutaway view of a
15 first embodiment of the present invention is illustrated. Figure 1A illustrates a fiber optic module 100 (a fiber optic transmitter, receiver, or transceiver module) for coupling to a plurality of fiber optic cables 101. The fiber optic cable 101 may be individual cables or a ribbon cable. Fiber optic
20 module 100 includes an optical element 103 and an electrical element 104. The electrical element 104 includes a printed circuit board (PCB) 106, a plurality of light transmitters 110 (i.e. emitters) or a plurality of light receivers 111 (i.e. photodetectors - shown on Figure 1B).

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The light transmitters 110 or receivers 111 are optoelectronic devices for communicating with optical fibers using light of various wavelengths or photons. An optoelectronic device is a device which can convert or transduce light or photons into an electrical signal or an electrical signal into light or photons. In the case of transmitters, the light transmitters 110 are packaged emitters that convert electrical signals into emitting light or photons, such as semiconductor lasers (i.e. a VCSEL) or LED, may be packaged in TO (transistor outline) cans. In the case of receivers, the receivers 111 are packaged photodetectors, that detect or receive light or photons and convert it into an electrical signal, such as a photo diode, may be packaged in a TO can. However other packages, housings or optoelectronic devices for receiving and transmitting light or photons may be used for the light transmitters 110 or receivers 111.

The shielded housing 119 has a top portion 119A and a bottom portion 119B that couple together and to the PCB 106. The top 119A and bottom portions 119B of the shielded housing 119 when properly assembled together sandwich the PCB 106 and encompass all high frequency electrical components while allowing the edges of the PCB 106 to extend outward outside of it to form the guide rails 162. Shielded housing 119 (and top portion 119A and bottom portion 119B) may be a metallized casing.

Each of the optoelectronic devices, transmitters 110 or receivers 111, have terminals to couple to traces or thruholes of the PCB 106. The PCB 106 includes electrical components 112 or 116 (transmitter integrated circuit (laser driver), or receiver integrated circuit (transimpedance amplifier and post amplifier), resistors, capacitors and other passive or active electrical components), male electrical connectors 113, and a ground plane 114. Electrical components 112 and 116 may be packaged with fixed PGA (pin grid array), fixed BGA (ball grid array), or other packaging technologies well known in the art.

The ground plane 114 is exposed on the top and/or bottom surface near one or more edges of the PCB 106 external to the shielded housing 119 to form the guide rails 162. In Figure 1, the ground plane is exposed near the edges of the left and right sides of the PCB 106. The exposed portion of ground plane 114 is a conductive surface such as a metallized surface formed of copper, silver, gold or other metal or alloy. The ground plane 114 preferably couples to ground or a low level of a power supply through the exposed top or bottom conductive surface of the guide rails 162 near the edges of the PCB 106.

Shielded housing 119 is coupled to ground plane 114.

At least one pin of the male electrical connectors 113 and 117 couple to the female electrical connectors 181 and 182 (shown in Figure 5) respectively when the fiber optic module 100 is inserted. The female electrical connectors 181

may be SFP (Small Form Pluggable) SMT (Surface Mount Technology) connectors. One or more pins of the male electrical connectors 113 and 117 allow electrical signals, power, and ground to be coupled into or out of the PCB 106.

5 A female electrical connector 181, pins of a male electrical connector 113, electrical components 112 necessary for controlling one light transmitter 110, a transmitter 110 and a lens 123 of the optical block form one transmitting channel. The electrical components 112 control the transmitter
10 110 and buffer the data signal received from a system for transmission over an optical fiber. A female electrical connector 182, pins of a male electrical connector 117, electrical components 116 necessary for controlling one light receiver 111, a light receiver 111 and a lens 121 of the
15 optical block form one receiving channel. Other combinations of components can form other communications channels. The electrical components 116 control the receiver 111 and buffer the data signal received from an optical fiber. The individual electrical components 112 and 116 of each channel allows the
20 optical output power to be automatically controlled at each of the channels individually.

 The shielded housing 119 of the fiber optic module 100 shunts electromagnetic fields to ground to avoid electro - magnetic interference (EMI) generated by other external
25 devices and the electrical components inside the housing.

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a. } Additional communication channels can be readily added to
the fiber optic module 100. PCB 106 may be enlarged along
with the ground plane 114 to include additional transmit or
receive communication channels, each channel having a separate
5 transmitter 111 or receiver 110 with the shielded housing 119
encompassing all high frequency electrical components of the
communication channels to provide EMI shielding. To reduce
the size of the PCB 106 or to incorporate more functions on
the PCB 106, a multi-channel IC may also be employed instead
10 of discrete ICs for each communication channel. The number of
male electrical connectors 113 and 117 may be reduced to make
the electrical interface more compact. For instance, only one
male electrical connector 113 and one male electrical
connector 117 may be employed. Furthermore, male electrical
15 connector 113 and male electrical connector 117 may be
combined into one male electrical connector. Also, the
grouping of multiple transmit or receive communication
channels on a PCB 106 allows the use of a common power supply
for those transmit or receive communication channels. Thus,
20 the module may be further simplified, reduced in size, and
made less expensive to manufacture. Furthermore, multiple
fiber optic modules 100 may be designed to plug in side by
side to form a single fiber optic module having additional
communication channels.
25 Thus, by grouping four transmit communication channels on a

detector 126 to receive light or photons. Light or photons emitted by the emitter 125 are coupled into lens 123, collected and focused into the optical fiber through the optical port 129. Light or photons, incident from a fiber optic cable coupled to the fiber optic module 100, is received through the optical port 130. Photons from the fiber optic cable are incident upon the lens 121. Lens 121 collects and focuses the incident light or photons from the fiber optic cable onto the detector 126 of the receiver 111. In order to keep the optical fibers 101 in alignment with the optical block 120, the fiber ferrules 131 are provided. The fiber ferrules 131 are inserted into the optical ports 129 and 130 of the optical block 120. While a light transmitter 110 and light receiver 110 are illustrated, optical subassembly 103' may include two light transmitters or two light receivers 111.

The optical element 103 includes a plurality of optical blocks 102 coupled to one or more EEs 104 to form fiber optic modules with various numbers of channels of various types (i.e. transmit, receive, or transceive combinations).

20 ^{Sub 22} Referring now to Figure 3, an exploded view of the optical subassembly 103' of the preferred embodiment of the present invention is illustrated. The optical subassembly 103' include a nose 151, fiber ferrules 131, an alignment plate 153, which also helps shield EMI from leaking into or out of the module and the optical block 120. The optical block 120 aligns

coupling and aligning a pair of LC terminated fiber optic
cables 101 into the fiber optic module 100. Each LC
receptacle 161 shown is a fiber optic receptacle for one
single direction fiber optic channel. The LC receptacles 161
5 in the nose 151 are preferably located without spacing between
each other. Due to the separation of the neighboring channels,
the fiber optic module 100 having multiple channels can comply
with FDA and IEC Class - 1 eye safety limits. This allows
easier handling of the fiber optic module 100.

10 Due to the size of LC connectors, TO-can size packages are
usable which allows the output power level of each individual
fiber optic channel to be separately monitored. Monitoring a
fiber optic channel involves splitting the light beam so that
a photodetector or photodiode receives a portion of the light
15 beam. The electrical output of the photodiode is then
measured to indicate the output power level of the fiber optic
channel. The relaxed spacing of the individual fiber optic
connectors of the present invention facilitate placing light
beam splitters within the TO can of the transmitter 110. The
20 light beam splitter splits the beam such that a portion of the
light beam lands on a photodiode within the TO can. The
photodiode's output is measured to monitor the output power of
the transmitter.

Thus, with each channel being separately monitored for
25 power output, each channel can be individually optimized

similar to the manner in which single channel data links are optimized. Therefore, a fiber optic module with parallel channels and separate power output monitoring such as this, can have superior performance with respect to the extinction
5 ratio, jitter, aging and temperature compensation.

The use of multiple LC connectors in the present invention can reduce cabling costs, especially in the cable termination cost. It also allows field termination while other alternative technology, such as the use of MPO/MTP connectors for the
10 parallel data links, cannot be terminated in the field, and pre-termination cabling increase the cost of fiber cable installation. There are also larger installed base and volume to support discrete termination connectors like LC than MPO/MTP connectors. Those skilled in the art will also
15 recognize that other fiber optic connectors such as, but not limited to, SC, MT - RJ, VF45, , and MU connectors, may be used in lieu of the LC connectors 161.

Referring now to Figure 4A, a disassembled view of the fiber optic (transmit/receive) module 100, a module cage 170,
20 and a host printed circuit board (PCB) 180 of an embodiment of the present invention is illustrated. The fiber optic module (transmit/receive) module 100 has two optical blocks 102 each having two LC receptacles 161 for coupling to fiber optic cables 101. A four-channel LC receptacle optical block can be
25 used instead of using two duplex LC receptacle blocks. The

fiber optic module 100 also includes guide rails 162 on opposite sides of the PCB 106 as shown. In the preferred embodiment, the guide rails 162 are at edges of PCB 106 and include an exposed conductive portion of the ground plane 114 on top and/or bottom surfaces of the edge of the PCB 106 which extend outside the shielded housing 119.

The module cage 170 is formed of a conductive material such as a metal and mounts to the host PCB 180. The cage is grounded through a spring-pin tabs, not shown in Figure 4A, to the chassis ground to shunt electromagnetic fields. To facilitate the assembly of the cage to the host PCB 180, tabs 175 of the module cage 170 may be snapped into or soldered onto the PCB 180 or coupled into thruholes 184 of the PCB 180 in any conventional manner. Thruholes 184 of the PCB 180 may be formed to include a bushing, a sleeve, via or other component.

With the module cage 170 mounted to the host PCB 180 and grounded to the system chassis during the system operation, the fiber optic (transmit/receive) module 100 hot-slides into and out of the module cage 170 through a front opening 176. The back 177 and sides 178-179 of the housing of the module cage are closed to provide EMI shielding. The beginning of the guide rails 162 of the fiber optic module 100 are inserted into guide rail slots 171 of the module cage 170. The remaining portion of the guide rails 162 slide along the guide

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rail slots 171 as the fiber optic module 100 is inserted into the module cage 170. At one point in insertion of the fiber optic module 100, the male electrical connectors 113 and 117 of the PCB 106 engage the female electrical connectors 181 and 182 respectively on the host PCB 180. With the fiber optic module 100 inserted into the module cage 170, the guide rails 162 of the PCB 106 couple to the guide rail slots 171 of the module cage in order to shunt electromagnetic fields from the shielded housing 119 through the guide rails 162, the guide rail slots 171, the tabs 175 and into the chassis ground.

While high frequency electronic components require shielding, low frequency electrical components and some passive components may not. Thus low frequency and passive electrical components of the fiber optic module 100, such as component 169 in Figure 5A, can be located on the PCB 106 outside its shielding 119.

Referring now to Figure 4B, a magnified cross-sectional view of the fiber optic module 100 inserted into the module cage 170 taken along section line 4B in Figure 4A is illustrated. In Figure 4B, the guide rail 162 is inserted into the guide rail slot 171 and are electrically and mechanically coupled together. The module cage 170 is preferably formed of a conductive material. In this case, the guide rail slots 171 are molded into the sides of the module cage as shown in Figure 4B. The guide rail slots 171 are of a

conductive material in order to make an electrical connection to the guide rails 162 of the fiber optic module 100.

As shown in Figure 4B, each of the one or more guide rails 162 of the fiber optic module 100 may be formed on the PCB 106 by providing a conductive trace 165 on a bottom surface of the PCB 106 and/or a conductive trace 166 on a top surface of the PCB 106. The conductive traces 165-166 are preferably a metal such as copper, silver, gold or other metal or alloy. The top conductive trace 166 couples to the top portion 119A of the electromagnetic shield 119. The bottom conductive trace 165 couples to the lower portion 119B of the electromagnetic shield 119. The conductive traces 165-166 are ground traces which are a part of the ground plane 114 of the fiber optic module 100.

To alternatively form the conductive guide rail slots 171, an inner surface 174 of the module cage 170 can be coupled to a conductive metal shield or have a conductive material applied thereto. In any case, the conductive material of the module cage, inner surface 174 or metal shield couples to a chassis ground to shunt electro-magnetic signals to ground.

The guide rails 162 of the PCB 106 and the guide rail slots 171 of the module cage 170 are of sufficient strength to support the weight of the fiber optic module 100.

Each guide rail slot 171 may include a retaining notch 173 which couples to the end of each guide rail 162 upon complete insertion of the fiber optic module 100 into the module cage 170. Removal of the fiber optic module 100 would then include
5 lifting the fiber optic module 100 so that the end of the guide rail clears the retaining notch.

Pins of the male electrical connectors 113 and 117 couple to the female electrical connectors 181 and 182 respectively when the fiber optic module 100 is substantially inserted into
10 the module cage 170. Because the guide rails 162 and guide rail slots 171 ground the fiber optic module 100 before power is coupled to the fiber optic module 100 via the electrical connectors, the module 100 will be hot pluggable in order to reduce down time.

15 Referring now to Figure 5A, a cut-away top view of a locking mechanism for coupling together the fiber optic module 100, the module cage 170, and the host PCB 180 is illustrated.

The locking mechanism includes a sliding arm 190, a rocker arm 192, a lever arm 195, and a cradle 197. With the fiber
20 optic module 100 substantially coupled to the module cage 170 and the female electrical connectors 181 and 182, the sliding arm 190 is actuated by a user's finger pushing on its end to unlock and partially eject the fiber optic module 100 from the module cage 170. The rocker arm 192 includes a hook 191 at

one end and a cam 193 at an opposite end. The hook 191 couples to an end point of the guide rail 162 of the fiber optic module to lock it in place. The sliding arm 190 includes a cutout 194 to interface with the cam 193 of the rocker arm 192. The cam 193 unlocks the fiber optic module 100 prior to its ejection when the cutout 194 pushes on the cam 193 to rotate the rocker arm 192 and unhook the hook 191 from the guide rail 162. The sliding arm 190 further includes a push tab 196 to couple to one end of the lever arm 195. As a user presses further on the end of the sliding arm 190 using his or her finger, the push tab 196 pushes on one end of the lever arm 195 to rotate it around a pivot point 198 in the cradle 197. The cradle 197 has fingers (not shown) that contact and engage the receiver printed circuit board 250 edge adjacent to the female electrical connectors 181 and 182. The cradle fingers push on the fiber optic module 100 so that it forcibly decouples male electrical connectors 113 and 117 of the fiber optic module 100 from the female electrical connectors 181 and 182 of the host PCB 180.

Referring now to Figure 5B, the unlocked and ejected position of the fiber optic module 100 in relation to the module cage 107 and the host printed circuit board 180 is illustrated. To engage and lock the fiber optic module 100 in place, a user pushes on the LC connectors 161. As the fiber optic module 100, slides into the cage, the rear of the

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the male electrical connectors 113, the electrical components 112 of the fiber optic module 100 process the data to generate electrical transmission signals which are coupled into the transmitter 110 for transmission as optical signals over one or more fiber optic cables 101. Transmitter 110 convert the electrical transmission signals from the electrical components 112 into pulses of light as the optical signal.

Alternatively, if data is received as an optical signal from one or more fiber optic cables 101, the receivers 111 convert the pulses of light into electrical signals which are coupled to electrical components 116 of the fiber optic module 100. Electrical components 116 process the data to generate electrical received signals which are coupled to pins of the male electrical connectors 117. The electrical components 112 and 116 may be either analog, digital or a mixed analog/digital type of electrical components. The capabilities of electrical components 112 and 116 may include storing data, encoding data, decoding data, controlling the transmitting or receiving of data, power management, deskewing, and other capabilities well known in the art of transmitting and receiving signals by means of fiber optic modules.

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a4 } In operation, electromagnetic fields may radiate to the EMI shield 153, the shielded housing 119, the ground plane 114 of the fiber optic module 100 as well as the module cage 170 and

shields of the female electrical connectors 181 and 182.

Electromagnetic fields radiating to the module cage 170 are shunted through the chassis ground. Similarly, electro -

magnetic fields that radiate to, or that are shunted to, the

shielded housing 119 are shunted to ground via the guide rail

162, surface of the guide rail slot 171, and then via the

chassis ground. The signal ground is connected to the male

electrical connectors 113 and 117, and female electrical

connectors 181 and 182. When plugged in, the signal ground is

first connected to avoid any damage to the module before the

signal is connected. In this way, the module can be hot-

plugged in and out without introducing any damage to the

module and the system.

The previous detailed description describes the fiber optic

module 100 as including two or more receivers or two or more

transmitters. However, one of ordinary skill can see that the

fiber optic module 100 may include two or more combinations

of a receiver and transmitter. One embodiment of the present

invention includes four transmitters. Another embodiment

includes four receivers. Yet another embodiment includes a

combination of four transmitters and receivers. Additionally,

the previous detailed description described one PCB board for

receive and transmit functions. However, the present

invention may be extended to a plurality of PCB boards placed

side by side substantially in parallel to providing transmit

or receive functionality or both into multiple channels of parallel fiber optic cables.

As those of ordinary skill will recognize, the present invention has many advantages over the prior art. One

5 advantage of the present invention is that each channel can be separately monitored for power output and therefore individually optimized. Since the present invention does not depend on VCSEL arrays, another advantage is that the alignment between electrical elements and optical elements can
10 be more easily performed using three dimensional alignment. Another advantage of the present invention is that spacing provided between fiber optic channels eases the attachment of heatsinks. Yet another advantage of the present invention is that the ample spacing between channels can reduce cabling
15 termination costs of multiple channel connections. Another advantage of the present invention is that ample spacing between channels of the multiple channels allows the fiber optic module to meet FDA and IEC Class - 1 eye safety limits. Another advantage of the present invention is that it
20 minimizes electromagnetic interference by shielding high frequency electrical components.

The preferred embodiments of the present invention are thus described. While the present invention has been described in particular embodiments, the present invention should not be
25 construed as limited by such embodiments, but rather construed

